PB-240 796

KENT LAKE, OAKLAND AND LIVINGSTON COUNTIES, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
Michigan Department of Natural Resources
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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
KENT LAKE
OAKLAND AND LIVINGSTON COUNTIES
MICHIGAN

EPA REGION V

WORKING PAPER No. 199

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

FEBRUARY, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identfying point sources and soliciting municipal participation in the Survey.

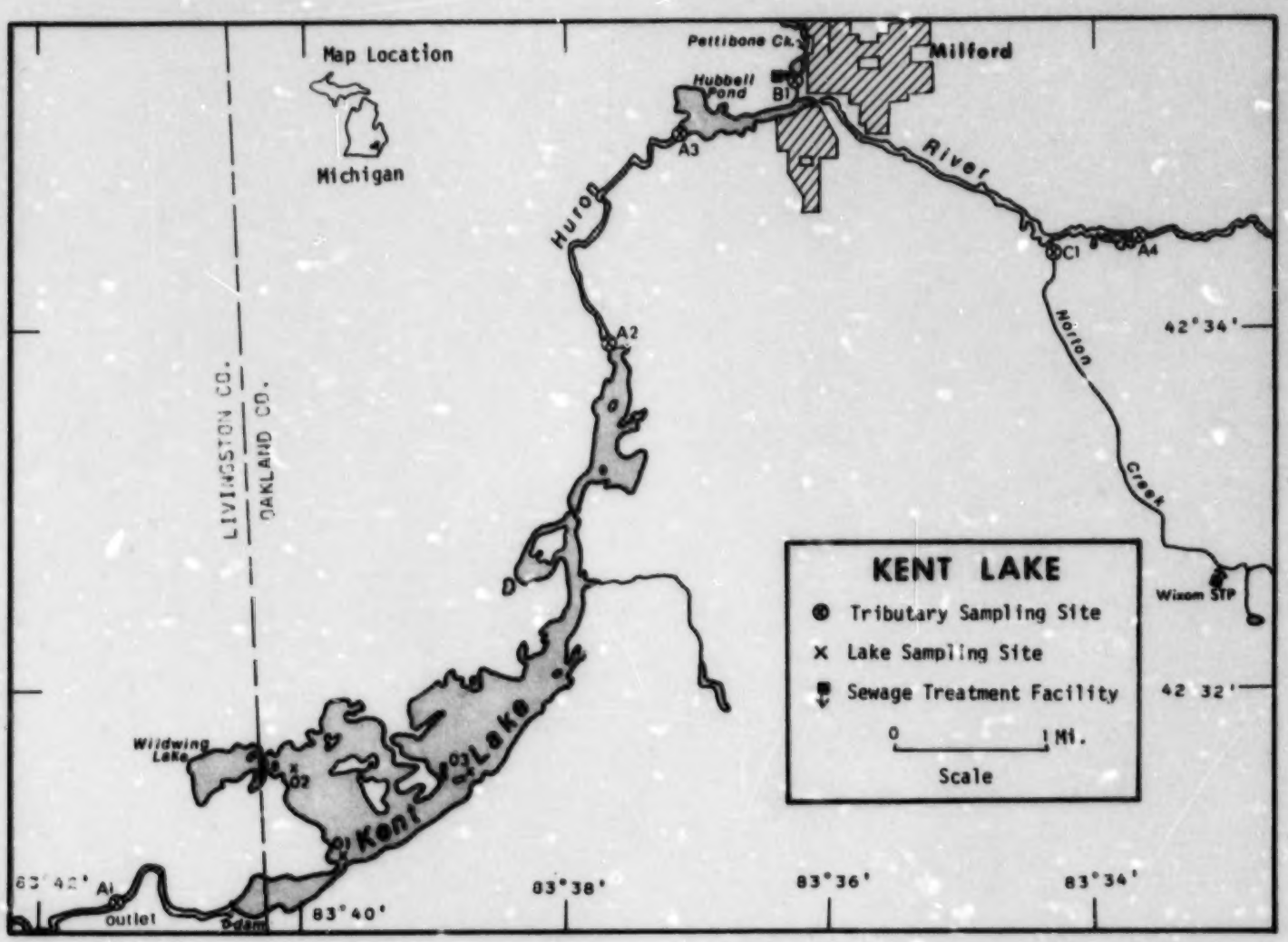
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


Map Location
Michigan
LIVINGSTON CO.
OAKLAND CO.
Pettibone Ck.
Milford
Hubbell Pond
B1
A3
Huron
River
C1
A4
A2
Norton
Creek
42°34'
Wixom STP
42°32'
Wildwing Lake
O2
O3
Lake
Kent
O1
A1
Outlet
Dam
83°42'
83°40'
83°38'
83°36'
83°34'
KENT LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0
1 Mi.
Scale

KENT LAKE

STORET NO. 2643

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others show that Kent Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, 14 had less mean total phosphorus, 10 had less mean dissolved phosphorus, and 11 had less mean inorganic nitrogen; of all 41 lakes sampled, 38 had less mean chlorophyll a, and 24 had greater mean Secchi disc transparency*.

Depletion of dissolved oxygen with depth was observed at station 2 in June and September, and Survey limnologists noted a heavy algal bloom in progress in September, 1972.

Ketelle and Uttormark (1971) report that algal blooms are intense and frequent in this lake.

B. Rate-Limiting Nutrient:

There was a significant nutrient loss in the algal assay sample, and the results are not representative of conditions in the lake at the time the sample was taken (09/20/72). However, the lake data indicate nitrogen limitation in June and September but phosphorus limitation in November.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Kent Lake received a total phosphorus load at a rate about five times that proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 13). However, the mean hydraulic retention time of Kent Lake is a relatively short 33 days, and Vollenweider's model may not be applicable.

It is calculated that the communities of Milford and Wixom contributed about 54% of the total phosphorus load to Kent Lake during the sampling year with Wixom contributing over 35% of the total.

Phosphorus removal at the 80% level is currently being provided at the Milford wastewater treatment plant. It is estimated that provision of the same level of phosphorus removal at the Wixom plant* would reduce the phosphorus load to the lake to about 10 lbs/acre/yr or 1.14 $g/m^2/yr$. While this loading rate would still be about 3½ times the eutrophic rate of 0.30 $g/m^2/yr$; in view of the questionable applicability of Vollenweider's model, it is likely the lower phosphorus loading rate would result in presistent phosphrous limitation in Kent Lake (see page 8) and a reduction in the incidence and severity of nuisance algal blooms.

* Operation of phosphorus removal facilities at the Wixom plant began in September, 1974.

2. Non-point sources (see page 12)--During the sampling year, the phosphorus export of the Huron River was a relatively low 45 lbs/mi^2 of drainage area. This export rate is similar to the export rates of unimpacted Michigan streams studied elsewhere.

In all, it is estimated that non-point sources, including precipitation, contributed about 46% of the total phosphorus load to Kent Lake during the sampling year.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 1,000 acres.
2. Mean depth: 6.6 feet.
3. Maximum depth: 38 feet.
4. Volume: 6,600 acre-feet.
5. Mean hydraulic retention time: 33 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Huron River	134.0 mi^2	90.6 cfs
Minor tributaries & immediate drainage -	12.4 mi^2	9.4 cfs
Totals	146.4 mi^2	100.0 cfs

2. Outlet -

Huron River	148.0 mi^2**	100.0 cfs

C. Precipitation***:

1. Year of sampling: 32.6 inches.
2. Mean annual: 33.1 inches.

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† MI Dept. Cons. lake inventory map (1957); mean depth from Fetterolf (1973).
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Kent Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake and from two or more depths at each station (see map, page v). During each visit, a single depth-integrated (15 feet or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 15 feet at station 1, 35 feet at station 2, and 9 feet at station 3.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

FALL VALUES

(11/13/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	6.0	6.3	6.4	6.5
Dissolved oxygen (mg/l)	8.8	9.3	9.0	10.6
Conductivity (μmhos)	430	444	440	465
pH (units)	8.0	8.1	8.1	8.2
Alkalinity (mg/l)	187	192	191	200
Total P (mg/l)	0.029	0.040	0.042	0.047
Dissolved P (mg/l)	0.012	0.015	0.015	0.017
NO_2 + NO_3 (mg/l)	0.080	0.091	0.080	0.140
Ammonia (mg/l)	0.220	0.326	0.335	0.410
		ALL VALUES		
Secchi disc (inches)	34	45	45	60

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
06/15/72	1. Melosira	3,007
	2. Cocconeis	2,174
	3. Fragilaria	761
	4. Pediastrum	725
	5. Stephanodiscus	543
	Other genera	2,935
	Total	10,145
09/20/72	1. Microcystis	4,932
	2. Anabaena	1,900
	3. Melosira	679
	4. Dinobryon	317
	5. Flagellates	271
	Other genera	634
	Total	8,733
11/13/72	1. Asterionella	5,940
	2. Flagellates	4,210
	3. Fragilaria	1,053
	4. Dinobyron	1,053
	5. Synedra	526
	Other genera	2,030
	Total	14,812

2. Chlorophyll *a* -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
06/15/72	01	16.2
	02	17.6
	03	30.1
09/20/72	01	41.3
	02	57.5
	03	52.5
11/13/72	01	19.6
	02	33.0
	03	37.7

C. Limiting Nutrient Study:

There was a loss of 44% of the dissolved phosphorus and 29% of the inorganic nitrogen in the assay sample between the time of sample collection and the beginning of the assay, and the assay results are not representative of conditions in the lake at the time the sample was collected (09/20/72).

The lake data indicate nitrogen limitation in June and September (N/P ratios = 9/1 and less) but phosphorus limitation in November (N/P = 28/1).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when two samples were collected. Sampling was begun in October, 1972, and was completed in October, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of the U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient concentrations in the Huron River at station A-4 and the mean annual ZZ flow.

The operator of the Milford wastewater treatment plant provided monthly effluent samples and corresponding flow data. However, the Village of Wixom did not participate in the Survey, and nutrient loads were estimated at 2.5 lbs P and 7.5 lbs N/capita/year.

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* See Working Paper No. 1.

In this report, all of the nutrient loads attributed to the two treatment plants are assumed to have reached Kent Lake during the sampling year. In the following loading tables, the loads given for the Huron River are those measured at station A-2 minus the STP loads.

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served††	Treatment	Mean Flow (mgd)	Receiving Water
Milford	4,699	act. sludge + P removal	0.700	Huron River
Wixom	2,010	act. sludge + P-removal**	0.201*	Norton Creek

2. Industrial - Unknown

† Howard, 1973.
†† 1970 Census.
* Estimated at 100 gal/capita/day.
** Phosphorus removal began in September, 1974.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Huron River	6,040	42.7
b. Minor tributaries & immediate drainage (non-point load) -	330	2.3
c. Known municipal STP's -		
Milford	2,610	18.4
Wixom	5,020	35.5
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation* -	160	1.1
Total	14,160	100.0

2. Outputs -

Lake outlet - Huron River 10,860

3. Net annual P accumulation - 3,300 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/yr	% of total
a. Tributaries (non-point load) -		
Huron River	132,290	66.1
b. Minor tributaries & immediate drainage (non-point load) -	18,910	9.4
c. Known municipal STP's -		
Milford	24,430	12.2
Wixom	15,080	7.5
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation* -	9,630	4.8
Total	200,340	100.0

2. Outputs -

Lake outlet - Huron River 215,840

3. Net annual N loss - 15,500 pounds

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs $P/mi^2/yr$	lbs $N/mi^2/yr$
Huron River	45	987

* See Working Paper No. 1.

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	14.2	3.3	202.3	loss*
grams/m^2/yr	1.59	0.37	22.5	-

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Kent Lake:

"Dangerous" (eutrophic rate)	0.30
"Permissible" (oligotrophic rate)	0.15

* The apparent loss of nitrogen may be due to nitrogen fixation in the lake, solubilization of previously sedimented nitrogen, unmeasured ground-water inputs, or underestimation of nitrogen contributions. However, a similar nitrogen loss has been observed in Shagawa Lake, Minnesota, which has been studied intensively by EPA's National Eutrophication and Lake Restoration Branch.

V. LITERATURE REVIEWED

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Ketelle, Martha J., and Paul D. Uttormark, 1971. Problem lakes of the United States. EPA Water Poll. Contr. Res. Ser., Proj. 16010 EHR.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	----------FALL VALUES---------- MEAN TOTAL P	MEAN DISS P	MEAN INORG N	----------ALL VALUES---------- SEC-MEAN SEC	MEAN CHLORA	1%-MIN UG
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.670	9.200
2641	CARO RESERVOIR	0.117	0.022	3.035	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.006	0.005	0.350	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.160	470.222	20.311	12.600
2606	BARTON LAKE	0.121	0.006	1.409	456.167	27.000	14.050
2609	BELLEVILLE LAKE	0.110	0.040	1.420	465.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.008	0.273	481.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.000	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	484.333	13.483	14.000
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	29.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.466	441.667	28.500	14.000
2640	JORDAN LAKE	0.100	0.144	1.900	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.350	477.600	25.600	12.200
2649	MANISTEE LAKE	0.010	0.010	0.304	491.333	6.317	11.300
2659	MUSKEGON LAKE	0.007	0.003	0.469	436.444	9.511	14.000
2665	PENTWATER LAKE	0.027	0.017	0.496	438.667	16.[illegible]	14.000
2671	RANDALL LAKE	0.246	0.103	0.810	497.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.103	435.500	8.133	9.600
2673	RUSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.000
2685	UNION LAKE	0.003	0.004	1.252	495.500	19.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	WONA LAKE	0.307	0.241	0.963	453.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.867	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLOPA	ALL VALUES 15-MIN DO*
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: SEC-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN OD	INDEX NO
2640	HOLLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
2641	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	180
2642	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	548
2683	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2686	BARTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2689	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	ROSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	WONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	143
2692	LONG LAKE	14 (5)	9 (3)	[illegible]	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2643 KENT LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 148.00

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2643A1	148.00	107.06	117.87	154.21	138.49	119.83	84.37	59.62	52.94	60.21	74.84	119.83	112.96	100.83
2643A2	134.00	93.80	105.00	149.00	163.00	117.00	76.30	57.30	46.30	52.40	62.70	76.10	89.50	90.57
2643ZZ	14.00	9.80	10.90	15.60	17.10	12.20	8.00	6.00	4.80	5.50	6.60	8.00	9.30	9.47

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 148.00
SUM OF SUB-DRAINAGE AREAS = 148.00

TOTAL FLOW IN = 1202.20
TOTAL FLOW OUT = 1202.23

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2643A1	10	72	80.00	29	133.00				
	11	72	163.00						
	12	72	163.00	2	210.00				
	1	73	210.00	7	257.00				
	2	73	161.00	4	197.00				
	3	73	296.00	4	180.00				
	4	73	178.00	6	157.00	22	205.00		
	5	73	131.00	6	106.00	20	97.00		
	6	73	224.00	2	164.00				
	7	73	122.00	7	139.00				
	8	73	86.00	4	69.00				
	9	73	64.00	8	49.00				
	10	73	98.00	13	86.00				
2643A2	10	72	86.00	29	134.00				
	11	72	121.00						
	12	72	128.00	2	109.00				
	1	73	187.00	7	225.00				
	2	73	138.00	4	181.00				
	3	73	235.00	4	155.00				
	4	73	201.00	6	242.00	22	183.00		
	5	73	151.00	5	144.00	22	114.00		
	6	73	159.00	2	179.00				
	7	73	101.00	7	91.00				
	8	73	74.00	4	66.00				
	9	73	49.00	8	40.00				
	10	73	81.00	13	72.00				

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2643 KENT LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
264322	10	72	9.00						
	11	72	13.00						
	12	72	13.00						
	1	73	20.00						
	2	73	14.00						
	3	73	25.00						
	4	73	21.00						
	5	73	16.00						
	6	73	17.00						
	7	73	11.00						
	8	73	7.80						
	9	73	5.20						
	10	73	8.50						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

264301
42 30 00.0 083 37 00.0
KENT LAKE
26 MICHIGAN

11EPALES
5

2111202
0016 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/15	10 39	0000	22.0	8.5	48	520	8.20	182	0.040	0.060	0.032	0.020
	10 39	0015	18.8	7.2		525	7.80	186	0.030	0.440	0.100	0.065
72/09/20	14 35	0000			42	590	8.10	151	0.060	0.100	0.038	0.017
	14 35	0004	21.2	8.5		600	8.15	149	0.050	0.100	0.042	0.024
	14 35	0011	21.4	7.4		590	8.10	152	0.050	0.150	0.056	0.026
72/11/13	13 45	0000			48	440	8.10	187	0.080	0.280	0.037	0.016
	13 45	0004	6.4	9.6		430	8.10	187	0.080	0.280	0.040	0.015
	13 45	0008	6.5	9.6		435	8.10	189	0.080	0.280	0.043	0.014

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	10 39	0000	16.2J
72/09/20	14 35	0000	41.3J
72/11/13	13 45	0000	19.6J

J* VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

264302
42 30 00.0 083 37 00.0
KENT LAKE
26 4ICHIGAN

11EPALLS 2111202
5 0035 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/15	11	30 0000	22.0	8.2		520	8.25	180	0.040	0.060	0.044	0.018
	11	30 0015	19.0	3.4		525	7.33	181	0.020	0.160	0.058	0.020
	11	30 0025	10.6	0.0		520	7.42	179	0.040	0.480	0.050	0.018
	11	30 0035	8.2	0.0		550	7.20	222	0.050	4.300	1.080	0.900
72/09/20	15	15 0000			36	590	8.30	149	0.050	0.120	0.027	0.014
	15	15 0004	21.4	9.7		590	8.30	149	0.060	0.110	0.040	0.020
	15	15 0015	21.3	8.8		590	8.30	148	0.050	0.100	0.035	0.019
	15	15 0020	19.4	2.0		600	7.55	160	0.050	0.440	0.072	0.050
	15	15 0025	12.5	0.0		600	7.15	190	0.100	1.990	0.355	0.238
72/11/13	14	05 0000			50	440	8.10	189	0.080	0.390	0.047	0.016
	14	05 0004	6.5	8.8		440	8.00	190	0.080	0.390	0.045	0.016
	14	05 0015	6.1	8.8		440	8.10	191	0.080	0.400	0.045	0.017
	14	05 0022	6.5	9.0		440	8.10	192	0.080	0.390	0.043	0.016
	14	05 0030	6.3	9.0		445	8.10	196	0.080	0.410	0.041	0.012

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	11	30 0000	17.6J
72/09/20	15	15 0000	57.5J
72/11/13	14	05 0000	33.0J

J* VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

032<

264303
42 30 00.0 085 37 00.0
KENT LAKE
26 MICHIGAN

11EPALES
5

2111202
0009 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/15	12	10 0000	23.4	8.0	42	510	8.36	185	0.040	0.030	0.042	0.022
	12	10 0009	22.1	7.8		510	8.15	178	0.040	0.070	0.046	0.025
72/09/20	15	00 0000			34	620	8.25	158	0.050	0.100	0.039	0.019
	15	00 0004	21.6	10.0		620	8.25	156	0.050	0.100	0.047	0.021
72/11/13	13	25 0000			60	465	8.20	199	0.130	0.220	0.029	0.013
	13	25 0004	6.0	10.6		460	8.20	200	0.140	0.220	0.034	0.013

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	12	10 0000	30.1J
72/09/20	15	00 0000	52.5J
72/11/13	13	25 0000	37.7J

J* VALUE KNOWN TO BE IN ERROR

026<

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/04

2643A1 LS2643A1
42 31 00.0 083 41 30.0
HURON RIVER
26 7.5 KENT LAKE
U/KENT LAKE
KENSNGTN RD BRDG 4.5 MI E .5 MI S BRGHTN
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09 50		0.104	1.450	0.240	0.025	0.090
72/12/02	11 00		0.156	1.470	0.230	0.010	0.038
73/01/07	10 08		0.310	3.000	0.280	0.006	0.032
73/02/04	10 00		0.210	0.490	0.066	0.007	0.035
73/03/04	10 00		0.240	0.690	0.074	0.011	0.045
73/04/06	11 30		0.066	0.830	0.027	0.006	0.045
73/04/22	14 00		0.050	0.840	0.240	0.026	0.055
73/05/06	11 34		0.01UK	0.780	0.007	0.009	0.055
73/05/20	13 15		0.01UK	0.725	0.032	0.013	0.050
73/06/02	10 40		0.019	0.860	0.033	0.012	0.045
73/07/07	15 30		0.031	1.040	0.058	0.022	0.060
73/08/04	10 30		0.130	1.680	0.092	0.031	0.060
73/09/08	10 00		0.046	1.050	0.052	0.011	0.090
73/10/13	14 00		0.044	0.900	0.078	0.008	0.045

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2643A2 LS2643A2
43 34 00.0 083 37 30.0
HURON RIVER
26 7.5 KENT LAKE
1/KENT LAKE
DA=SUN RD BRDG 2 MI SW MILFORD BELO STP
11EPALES 21112U4
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	11 05		0.110	0.500	0.140	0.015	0.038
72/12/02	13 10		0.100	1.100	0.140	0.015	0.048
73/02/04	09 00		0.270	0.510	0.084	0.011	0.035
73/03/04	13 00		0.240	0.720	0.089	0.013	0.060
73/04/04	13 00		0.147	0.536	0.048	0.008	0.035
73/04/22	10 15		0.103	0.740	0.054	0.013	0.063
73/05/05	11 10		0.050	0.640	0.056	0.016	0.040
73/05/22	11 45		0.044	1.230	0.080	0.017	0.050
73/06/02	10 40		0.032	0.800	0.056	0.017	0.050
73/07/07	14 30		0.100	0.420	0.120	0.035	0.070
73/09/04	10 45		0.120	1.200	0.154	0.056	0.100
73/04/04	09 20		0.044	0.740	0.080	0.066	0.145
73/10/13	12 30		0.050	0.740	0.054	0.026	0.110

STORET RETRIEVAL DATE 75/02/04

2643A3 LS2643A3
42 35 00.0 083 37 00.0
HURON RIVER
26 7.5 MILFORD
T/KENT LAKE
BELO HUBBELL POND DAM WSW MILFORD MBVSTP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/24	11 20		0.100	0.650	0.098	0.010	0.030
72/12/02	10 00		0.164	1.340	0.096	0.011	0.026
73/01/07	08 50		0.310	0.780	0.115	0.008	0.027
73/02/04	09 00		0.290	0.595	0.080	0.009	0.030
73/03/04	13 30		0.310	0.740	0.056	0.010	0.050
73/04/06			0.170	0.630	0.044	0.005K	0.025
73/04/22	09 54		0.090	1.200	0.029	0.008	0.045
73/05/05	10 30		0.042	0.780	0.063	0.008	0.035
73/05/22	11 00		0.011	1.700	0.032	0.007	0.042
73/06/02	11 10		0.025	1.050	0.115	0.014	0.040
73/07/07	14 45		0.010K	0.710	0.018	0.017	0.055
73/08/04	11 00		0.015	1.050	0.021	0.020	0.057
73/09/04	09 30		0.016	0.840	0.025	0.011	0.035
73/10/13	12 45		0.044	0.645	0.033	0.007	0.045

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2043A4 LS2043A4
42 34 30.0 083 33 30.0
HURON RIVER
26 7.5 MILFORD
T/KENT LAKE
WIXOM BRDG 1.75 MI SE MILFORD
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/24	12 25		0.052	0.600	0.105	0.005K	0.013
72/12/02	11 00		0.120	1.540	0.087	0.005K	0.017
73/01/07	10 10		0.260	0.420	0.084	0.005K	0.013
73/02/04	10 30		0.294	0.335	0.058	0.005K	0.015
73/03/04	14 45		0.260	0.630	0.046	0.005K	0.020
73/04/06	12 30		0.190	0.580	0.011	0.005K	0.015
73/04/22	10 31		0.138	0.680	0.007	0.005K	0.020
73/05/05	09 30		0.100	1.430	0.066	0.005K	0.015
73/05/22	10 45		0.063	0.940	0.046	0.005K	0.015
73/06/02	11 45		0.046	1.000	0.038	0.006	0.015
73/07/07	15 15		0.010K	1.100	0.020	0.008	0.030
73/08/04	12 40		0.012	1.210	0.056	0.007	0.020
73/09/08	09 25		0.021	1.320	0.067	0.013	0.020
73/10/13	13 15		0.010K	0.750	0.025	0.005K	0.025

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

264381 LS264381
42 35 30.0 083 36 00.0
PETTIBONE CREEK
26 7.5 MILFORD
T/KENT LAKE
CITY BRDG SW EDGE MILFORD ON LIBERTY ST
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	11 35		0.047	0.400	0.052	0.013	0.034
72/12/02	10 45		0.080	0.460	0.022	0.008	0.021
73/02/04	09 40		0.126	0.310	0.017	0.005K	0.015
73/03/04	14 00		0.189	0.420	0.033	0.005K	0.015
73/04/06	12 15		0.063	0.420	0.013	0.005K	0.010
73/04/22	09 20		0.040	0.580	0.026	0.008	0.020
73/05/05	09 45		0.014	0.500	0.010	0.013	0.015
73/05/22	10 30		0.010K	0.980	0.010	0.005K	0.015
73/06/02	11 15		0.010K	0.580	0.050	0.005K	0.015
73/07/07	15 00		0.010K	0.560	0.025	0.007	0.010
73/08/04	11 15		0.010K	0.640	0.014	0.005K	0.010
73/09/04	09 00		0.010K	1.900	0.071	0.005K	0.020
73/10/13	12 55		0.010K	0.420	0.018	0.005K	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2643C1 LS2643C1
42 34 30.0 083 34 00.0
NORTON CREEK
26 7.5 MILFORD
T/KENT LAKE
GARDEN RD BRDG 1.5 MI SE OFMILFORD
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	12 15		0.250	0.450	0.200	0.072	0.132
72/12/02	12 30		0.430	1.000	0.273	0.025	0.092
73/01/07	09 20		0.270	2.730	0.200	0.005K	0.013
73/02/04	10 15		0.378	1.150	0.360	0.042	0.130
73/03/04	14 30		0.360	1.260	0.210	0.054	0.155
73/04/06	12 20		0.220	0.960	0.115	0.076	0.150
73/04/22	09 40		0.044	1.500	0.096	0.105	0.200
73/05/05	08 45		0.032	1.750	0.065	0.067	0.130
73/05/22	11 29		0.020	1.320	0.036	0.100	0.170
73/06/02	11 30		0.010K	1.260	0.042	0.089	0.130
73/07/07	15 05		0.010K	1.100	0.147	0.231	0.370
73/08/04	12 30		0.010K	1.700	0.132	0.189	0.375
73/09/08	09 10		0.220	0.930	0.210	0.066	0.185
73/10/13	13 00		0.150	1.050	0.139		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

264350 P0264350 P004500
42 35 00.0 083 37 00.0
MILFORD
26 7.5 MILFORD
T/KENT LAKE
MUHON RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/02/01	08 00								
CP(T)-			0.115	7.150	0.103	0.400	0.885	0.756	0.720
73/02/02	08 00								
73/03/06	09 00								
CP(T)-			0.140	9.300	3.100	0.666	1.200	0.800	0.750
73/03/07	09 00								
73/04/01	09 00		0.195	10.000	0.350	0.420	0.720	0.780	0.720
73/04/30	08 00								
CP(T)-			0.130	13.200	1.160	0.820	1.350	0.760	0.700
73/05/01	08 00								
73/06/07	08 00								
CP(T)-			0.115	5.600	1.500	0.210	1.850	0.980	0.790
73/06/08	08 00								
73/07/10	08 00								
CP(T)-			0.440	11.500	1.100	0.210	1.100	0.888	0.860
73/07/11	08 00								
73/08/05	08 00								
CP(T)-			0.340	17.800	6.600	0.250	1.000	0.851	0.850
73/08/06	08 00								
73/09/26	09 00								
CP(T)-			1.320	2.200	0.180	0.740	0.780	1.100	0.750
73/09/27	09 00								
73/12/04	08 00								
CP(T)-			0.080	11.500	0.580	0.640	1.650	0.787	0.680
73/12/05	08 00								
74/02/06	08 00								
CP(T)-								0.779	0.720
74/02/07	08 00								
74/06/02	08 00								
CP(T)-			0.280	20.000	5.600	0.650	1.400	0.771	0.830
74/06/03	08 00								
74/07/09	08 00								
CP(T)-			0.040	7.500	0.065	0.360	0.630	1.400	0.850
74/07/10	08 00								